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Alien flora of the Garden Route National Park, South Africa

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ABSTRACT

Invasive alien plants (IAPs) are regarded as the leading ecological threat to the recently established Garden Route National Park (GRNP) along the Cape south coast of South Africa. The extensive and long-standing presence of commercial forestry in the region has contributed substantially to the current load of IAPs in the area. The GRNP's fragmented, linear configuration and a multitude of anthropogenic and ecological disturbances in the landscape contribute to its susceptibility to alien plant invasion. In compiling a checklist of alien flora for the park, we recorded 244 species of alien plants in 77 families, of which 58% (141 species) have not been recorded for the region by the Southern African Plant Invaders Atlas. Of the GRNP alien plant species, 9% are casual aliens, 27% naturalised, 59% invasive, and 5% transformers. Among South African National Parks, the GRNP ranks second in terms of alien plant species richness and has the largest proportion of invasives and transformers for those parks where invasion status was recorded. Transformer species in the GRNP are almost exclusively tree species introduced from Australasia >100 years ago for forestry purposes or sand stabilisation. Natural habitat within the park that is most threatened by IAPs is fynbos shrublands and riparian habitat. Our analysis indicates that the pressure of IAPs in the GRNP is escalating. Substantial and sustained management actions will be required to mitigate impacts from alien plant invasions in the GRNP. We identified species posing emerging or escalating threats that require improved control or regulation.

1. Introduction

Biological invasions are among the foremost threats to biodiversity conservation globally (Mooney and Hobbs, 2000). At a regional scale, invasive alien plants (IAPs) are likewise regarded as the leading ecological threat to South Africa's Garden Route National Park (GRNP) (SANParks, 2010). The establishment of the GRNP in 2005 along the Cape south coast of South Africa incorporated parcels of land that have in the past been variously managed for water conservation, biodiversity conservation, plantation forestry using IAPs, and timber harvesting from indigenous forests. Land uses in the region that are most significant in terms of extent, socio-economic importance and residence time, are agriculture and forestry. The forestry industry, in particular, has contributed greatly to the high number of alien plants in the region (Richardson, 1998; Latimer et al., 2004; Kraaij et al., 2011).

Historical accounts of the introduction of alien plant species into the Garden Route region for forestry purposes are provided by Phillips (1931, 1963), Poynton (1977) and Olivier (2009). The first state-owned plantations were established in 1883 close to Knysna, focussing on *Pinus*, and to a lesser extent, *Eucalyptus* species (Van der Zel and Brink, 1980; Olivier, 2009). From 1891, forest gaps arising from the harvesting of indigenous trees were planted with alien trees — often at a scale of >100,000 alien trees per year, mainly *Acacia* and *Eucalyptus* species. Since 1892, belts of *Pinus*, *Eucalyptus* and *Quercus* species were planted to protect forest margins against fire (Phillips, 1963). Since the 1800s, Australian *Acacia* species have been planted extensively on coastal sands to stabilise dynamic dune systems (Avis, 1989). State-owned and private plantations in the region grew steadily up until the 1980s (Van der Zel and Brink, 1980) to a current extent of approximately 70,000 ha between the towns of George in the west and Kareedouw in the east. Numerous species introduced in trials failed to establish or exhibited poor growth (Geldenhuys et al., 1986) but a subset of forestry species (notably *Pinus*, *Acacia* and *Eucalyptus*) became the most aggressive invaders in the region (Richardson, 1998).

Abbreviations: CARA, Conservation of Agricultural Resources Act; GRNP, Garden Route National Park; IAP, invasive alien plant; NEMBA, National Environmental Management: Biodiversity Act; NP, national park; SAPIA, Southern African Plant Invaders Atlas.

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Apart from historical aspects, the nature and configuration of an area may determine its susceptibility to invasion by alien biota (Saunders et al., 1991). The GRNP is a highly fragmented protected area, consisting of approximately 30 detached portions, arranged in a near-linear configuration. The park thus has a high edge-to-area ratio, with farmland, plantations and towns (George, Sedgefield, Knysna, Plettenberg Bay, and Storms River) dispersed along its boundaries, making it particularly susceptible to edge effects, including the immigration of species (Alston and Richardson, 2006). The N2 national road linking Cape Town and Port Elizabeth furthermore runs in a west–east direction throughout the length of the GRNP, with many secondary routes running through or in close proximity to the park. The park has numerous access points and trails for vehicles, cyclists, and hikers, all of which presumably act as conduits for alien plant introduction and dispersal (Pickering and Mount, 2010). Disturbance is another important determinant of invasibility (Hobbs and Huenneke, 1992) and natural disturbance events are common, particularly fires in fynbos shrublands (Kraaij et al., 2013), and floods (flow variability; Russell, 2013) associated with the numerous short, steep rivers dissecting the landscape.

The aim of this article was to present a checklist of alien plants for the GRNP. Alien plant checklists provide a benchmark against which species occurrence can be measured in future, enabling the detection of new introductions and potentially successful eradications, or changes over time in the invasion status of species. We characterised the alien flora of the GRNP in terms of invasion status and other historical and ecological attributes to improve understanding of the dynamics of alien plant invasion in the park. Ultimately these findings should facilitate biodiversity conservation by informing IAP management efforts.

2. Methods

2.1. Study area

The study area is the Garden Route National Park (GRNP) (33.80°S 22.50°E–34.15°S 24.20°E), extending over 145,000 ha between George in the west and Kareedouw in the east (c. 150 km east–west extent), and the watershed of the Outeniqua- and Tsitsikamma Mountains in the north and the Indian Ocean in the south (c. 40 km north–south extent) (Fig. 1). The GRNP straddles the Eastern Cape and Western Cape Provinces, and five local municipalities, i.e., George, Knysna, Plettenberg Bay, Kou-Kamma, and Baviaans Municipalities. The park consists of four formerly different administrative entities: The Tsitsikamma Coastal and Forest National Parks (NPs) proclaimed in 1964; The Wilderness NP proclaimed in 1983; The Knysna National Lake Area proclaimed in 1985 to protect the Knysna Estuary; and State Forests (comprising large tracts of montane fynbos, indigenous forest and commercial plantation) formerly managed by Department of Water Affairs and Forestry and proclaimed a National Park in 2011 (Government Gazette, 2011).

The terrestrial vegetation largely comprises fire-prone fynbos shrublands (c. 70,000 ha; South Outeniqua Sandstone Fynbos, Tsitsikamma Sandstone Fynbos and lesser areas of various lowland fynbos types) and fire-resistant Southern Afrotemperate Forest (c. 41,000 ha) (Mucina and Rutherford, 2006) (Fig. 1). Fynbos is considered to be more susceptible to alien plant invasions than forest (Macdonald and Richardson, 1986; Henderson, 2007). Smaller areas of coastal vegetation are associated with estuarine and seashore habitats. Another c. 1,500 ha comprise various land uses such as transformed land, fire belts, forest clearings, pasture, forest villages, office terrain and roads, all of which increase the potential for invasive plants to be introduced and spread. Lakes, estuaries and large river bodies encompass about 3,500 ha and the Tsitsikamma NP Marine Protected Area 27,000 ha. Large tracts of commercial plantations adjacent to the park are interspersed with the park's natural vegetation. In the western half of the GRNP approximately 25,000 ha of these plantations will be clearfelled to revert to the GRNP by the year 2020 to be rehabilitated to fynbos or forest.

The topography of the GRNP is characterised by rugged mountains, foothills and coastal plains (altitudinal range 0–1675 m.a.s.l.). The coastline is rocky in places but long sandy beaches are common. Deep ravines are cut through the landscape in a north south direction by the Touw-, Homtini-, Goukamma-, Knysna-, Groot-, Bloukrans- and Storms Rivers. The Cape Fold Belt dominates the geology and largely consists of Table Mountain Sandstone with smaller areas of the Bokkeveld Group, Enon Formation, George Granites and Kaaimans Formation (Tham and Johnson, 2006). Aeolian sands deposited during the Quaternary cover the coastal plateau between Knysna and Plettenberg Bay. A narrow coastal strip of migrating and vegetation-stabilised dunes occur on the coastal lowlands (Illenberger, 1996).

Mean annual rainfall ranges between 800 and 1100 mm and increases from west to east and from south to north with an increase in altitude. Rain falls throughout the year but peaks in spring and autumn (Tyson and Preston-Whyte, 2000). In winter, frost occurs in some areas and snow on the higher mountain peaks. Summers are mildly warm (22–25 °C) and winters mild (18–21 °C). The mild weather can be partly attributed to the influence of the warm Agulhas oceanic current. Southeasterly winds prevail in summer and north to northwesterly winds (hot dry bergwinds) are common in autumn and winter, whilst southwesterly winds occur throughout the year (Tyson and Preston-Whyte, 2000).

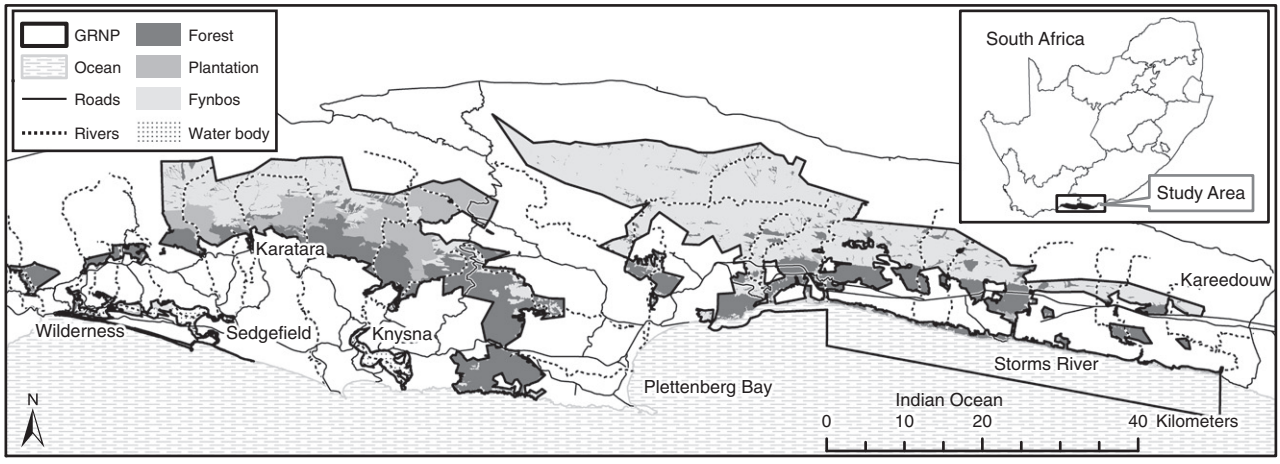

Fig. 1. Extent of the Garden Route National Park (GRNP) and the distribution of fynbos, indigenous forest, plantations and water bodies.

Table 1
Attributes reported for each alien plant species in the checklist. Combinations of categories are possible for *Origin*, *Reason for introduction*, *Habitat of occurrence*, and *Control*.

Invasion status	Categorised as casual alien, naturalised, invasive, or transformer (after Richardson et al., 2000 and Pyšek et al., 2004). Species considered to be emerging or escalating threats in the study area are indicated with '!'.
Origin	The geographic area that a plant is native to; delineated on continental boundaries (after http://en.wikipedia.org/wiki/Continental_boundary except where indicated otherwise), i.e. North America 'N Am' (excluding Central America), South America 'S Am' (including Central America), Mediterranean 'Med' (selected based on its floristic similarity to the study area), Eurasia 'Eur' (excluding Mediterranean), Africa 'Afr' (excluding Mediterranean but including Madagascar; and indicating if from South Africa 'SA' specifically, and thus extralimital), and Australasia 'Aus'.
Growth form	Classified as tree (height >3 m), shrub (<3 m), graminoid (including Poaceae, Restionaceae, Cyperaceae, Juncaceae), geophyte, herb (herbaceous), creeper, succulent, or fern.
First record	The year in which an alien plant was first recorded in the vicinity of the study area followed by a suffix, i.e. 'i', date of introduction or first planting by the forestry industry according to published sources (e.g. Phillips, 1931, 1963; Poynton, 1977); 'c', publication date of checklists; or 'h', date of photo- or herbarium specimen collection. For most species the first record is unknown, we therefore additionally indicated the estimated residence time.
Residence time	The number of years an alien species has been present in the region, i.e. less than 20 years; 20–100 years; or more than 100 years.
Most recent record	The year of most recent collection or observation, to allow for potential future detection of local eradication or disappearance of species from the area.
(Likely) reason for introduction	'A', with or for Agriculture; 'E', as an Edible plant, 'F', with or for Forestry (including for the stabilisation of sand); 'G', with or for Grazing; 'H', for Horticulture; 'M', plants known to have Medicinal use (including narcotics); or 'W', as a Weed (where other mode is unlikely).
Habitat of occurrence	Distinguishing among Forest 'For', Fynbos 'Fyn', Thicket 'Thi' and Riparian 'Rip' in natural or near-natural states; Wetland 'Wet' being periodically inundated land, transitional between terrestrial and aquatic ecosystems (Van Ginkel et al., 2011); Aquatic 'Aqu' meaning growing in water; Disturbed 'Dis' being disturbed fynbos, forest or riparian habitat, showing some resemblance of natural structure and function but altered (may include semi-natural roadsides); and Transformed 'Tra' being habitat that has lost its original natural structure and function, often due to earth works (e.g. transformed roadsides, pastures, gardens, areas associated with human habitation).
CARA status	Listed as Category 1, 2, or 3 invasive species (or not listed) by the Conservation of Agricultural Resources Act (CARA, Act 43 of the Republic of South Africa, 1983) for the Western or Eastern Cape Province, whichever was the highest category.
NEMBA status	Listed as Category 1, 2, or 3 invasive species (or not listed) by the published draft alien and invasive species lists under the National Environmental Management: Biodiversity Act (NEMBA, Act 10 of the Republic of South Africa, 2004) for the Western or Eastern Cape Province, whichever was the highest category.
SAPIA	Whether or not a species is recorded in the Southern African Plant Invaders Atlas (SAPIA) (Henderson, 2007, but using the updated database) as present in the quarter degree squares that encompass the study area. Indicated as 'Y' if recorded by SAPIA to species level, 'Yx' if recorded by SAPIA to genus level.
Control	Whether or not control measures are implemented in the park and the type of control measures, i.e. mechanical ('M'), chemical ('C') or biological ('B').

2.2. Checklist

Spear et al. (2011) presented checklists of alien biota for all South Africa's NPs but their list of alien plants for the GRNP was largely sourced from unpublished data (observations and specimen collections, 1982–2011) of the main author of the present paper. Our checklist comprises the species listed for the GRNP by Spear et al. (2011) in addition to data obtained from (i) subsequent field observations and plant specimen collections (2011–April 2014), (ii) literature searches for plant lists or vegetation descriptions (Jacot Guillarmod, 1982; Hanekom et al., 1989) and forestry planting records (Phillips, 1963; Poynton, 1977) pertaining to the study area; and (iii) incorporation of additional herbarium collections that existed for the GRNP's former administrative entities.

We listed alien plants alphabetically per family within the following taxa: Pteridophyta, Gymnosperms, Monocotyledons and Dicotyledons. Nomenclature follows 'The Plant List' (http://www.theplantlist.org/). In compiling the list, we followed the approach and terminology proposed by Richardson et al. (2000) and Pyšek et al. (2004) in order to improve repeatability and reduce error in alien species listing endeavours (McGeoch et al., 2012). Accordingly, our checklist includes casual aliens (plants not forming self-replacing populations, relying on repeated introductions for persistence), naturalised plants (sustaining self-replacing populations for at least 10 years), invasive plants (producing reproductive offspring, spreading >100 m in 50 years via seed, or >6 m in 3 years via vegetative means) and transformers (invasive plants changing the character, condition, form or nature of ecosystems over substantial areas; Wells et al., 1986) recorded in the study area. Casual aliens were excluded if present in personnel villages, office complexes and tourist camps, unless listed as an invasive species by the draft National Environmental Management: Biodiversity Act (NEMBA, Act 10 of the Republic of South Africa, 2004), e.g. *Tipuana tipu*. Casual aliens planted in arboreta were included. For each species in the checklist we reported various historical and ecological attributes as described in Table 1. We furthermore assessed the incidences of error or uncertainty generally associated with alien species listing (McGeoch et al., 2012) in our list.

3. Results

Two hundred and forty four species of alien plants in 77 families have been recorded from the GRNP (Table 2). Families with the largest

Table 2
Checklist of alien plant species recorded in the Garden Route National Park. Attributes reported are defined in Table 1.

Family	Species	Invasion status	Origin	Growth form	First record	Residence time	Most recent record	Reason for introduction	Habitat	CARA	NEMBA	SAPIA	Control
PTERIDOPHYTA													
Cyatheaceae	*Sphaeropteris cooperi* (F. Muell.) R.M. Tryon	Invasive!	Aus	Fern		<20	2014	H	For, Dis, Tra			Y	M
Dryopteridaceae	*Cyrtomium micropterum* (Kunze) Ching	Invasive	Eur	Fern	2014	<20	2014	H	For			Yx	
Nephrolepidaceae	*Nephrolepis cordifolia* (L.) C. Presl	Invasive!	N Am, S Am	Fern		20–100	2014	H	Fyn, Dis	3	1b	Y	M,C
Pteridaceae	*Adiantum raddianum* C.Presl	Invasive	S Am	Fern		20–100	2014	H	For				
Pteridaceae	*Pteris tremula* R.Br.	Invasive	Aus	Fern		20–100	2014	H	Dis, Tra				
Salviniaceae	*Salvinia adnata* Desv.	Invasive	S Am	Herb		<20	2014	H	Aqu	1	1b	Yx	B
GYMNOSPERMS													
Araucariaceae	*Araucaria cunninghamii* Mudie	Casual	Aus	Tree	1930i	20–100	2014	F	For				
Araucariaceae	*Araucaria heterophylla* (Salisb.) Franco	Casual	Aus	Tree	1876i	>100	2014	F	For				
Cupressaceae	*Chamaecyparis lawsoniana* (A. Murray bis) Parl.	Casual	N Am	Tree	1930i	20–100	2014	F	For				
Araucariaceae	*Agathis australis* (D. Don) Lindl.	Casual	Aus	Tree	1930i	20–100	2014	F	For				
Cupressaceae	*Sequoia sempervirens* (D. Don) Endl.	Casual	N Am, S Am	Tree	1930i	20–100	2014	F	For				
Pinaceae	*Pinus canariensis* C.Sm.	Naturalised	Med	Tree	1892i	>100	2014	F	Fyn	2	3		M,C
Pinaceae	*Pinus elliottii* Engelm.	Invasive	N Am	Tree	1930i	20–100	2014	F	Fyn, Dis	2	1b		M
Pinaceae	*Pinus halepensis* Mill.	Naturalised	Med	Tree	1892i	>100		F	Dis	2	2	Y	M
Pinaceae	*Pinus pinaster* Aiton	Transformer	Med	Tree	1890i, 1985c	>100	2014	F	Fyn, Dis, Tra	2	1b	Y	M
Pinaceae	*Pinus radiata* D. Don	Transformer	N Am	Tree	1910i, 1985c	>100	2014	F	Fyn, Dis, Tra	2	1b	Y	M
Pinaceae	*Pinus taeda* L.	Invasive	N Am	Tree	1930i	20–100	2014	F	Fyn, Dis	2	2		
Podocarpaceae	*Podocarpus henkelii* Stapf ex Dallim. & B.D. Jacks	Casual	Afr (SA)	Tree		20–100	2014	F	For				
MONOCOTYLEDONS													
Alliaceae	*Allium triquetrum* L.	Naturalised	Med	Geophyte	1982c	20–100	1982	H	Wet			Y	
Alliaceae	*Nothoscordum gracile* (Aiton) Stearn	Naturalised	S Am	Geophyte	2008h	20–100	2014	H	Dis				
Amaryllidaceae	*Leucojum vernum* L.	Naturalised	Eur	Geophyte		20–100	2014	H	Tra				
Asparagaceae	*Agave americana* L.	Casual	S Am	Succulent		20–100	2014	A,H	Dis, Tra		2	Y	M,C
Asparagaceae	*Agave attenuata* Salm-Dyck	Naturalised	S Am	Succulent		20–100	2014	H	Dis, Tra		2		M,C
Asparagaceae	*Yucca aloifolia* L.	Naturalised	N Am	Succulent		20–100	2014	H	Dis, Tra				M,C
Cyperaceae	*Cyperus esculentus* L.	Invasive	Eur, Med, N Am	Graminoid		20–100	2014	E	Dis				
Cyperaceae	*Cyperus papyrus* L.	Invasive	Afr (SA)	Graminoid		20–100	2014	H	Rip, Aqu				
Cyperaceae	*Schoenoplectus triqueter* (L.) Palla	Invasive	Eur	Graminoid	1982c	20–100	1982	W	Wet				
Iridaceae	*Iris pseudacorus* L.	Naturalised	Afr, Eur	Geophyte		20–100	2014	H	Dis		1a		
Iridaceae	*Sisyrinchium angustifolium* Mill.	Invasive	N Am	Geophyte		<20	2014	H	Dis			Yx	
Musaceae	*Musa acuminata* Colla	Casual	Eur	Shrub		20–100	2014	E	Tra				M
Poaceae	*Agrostis avenacea* J.F.Gmel.	Naturalised	Aus	Graminoid	2001h	20–100	2001	W	Fyn				
Poaceae	*Arundo donax* L.	Invasive	Med	Graminoid		20–100	2014	H	Rip, Aqu, Dis, Tra	1	1b	Y	M,C
Poaceae	*Avena fatua* L.	Invasive	Eur	Graminoid		20–100	2014	A	Dis, Tra				
Poaceae	*Axonopus affinis* Chase	Naturalised	N Am	Graminoid		20–100	2007	A	Dis				
Poaceae	*Briza maxima* L.	Invasive	Med	Graminoid		20–100	2014	H	Dis, Tra				
Poaceae	*Briza minor* L.	Invasive	Med	Graminoid	1966h	20–100	2014	H	Dis, Tra				
Poaceae	*Bromus catharticus* Vahl	Invasive	S Am	Graminoid	1982c	20–100	2014	A	Dis, Tra				
Poaceae	*Bromus diandrus* Roth	Invasive	Med	Graminoid		20–100	2014	A	Dis, Tra				
Poaceae	*Cortaderia selloana* (Schult. & Schult.f.) Asch. & Graebn.	Invasive!	S Am	Graminoid		20–100	2014	H	Fyn, Dis, Tra	1	1b	Y	M,C
Poaceae	*Digitaria sanguinalis* (L.) Scop.	Naturalised	Eur	Graminoid	1966h	20–100	1966	W	Dis				
Poaceae	*Festuca arundinacea* Schreb.	Naturalised	Eur	Graminoid	2011h	20–100	2014	A	Tra				
Poaceae	*Lagurus ovatus* L.	Invasive!	Med	Graminoid		20–100	2014	H	Dis, Tra				
Poaceae	*Lolium multiflorum* Lam.	Invasive	Eur	Graminoid	1982c	20–100	2014	A	Dis, Tra				
Poaceae	*Lolium perenne* L.	Invasive	Eur	Graminoid	1982c	20–100	2014	A	Dis, Tra				
Poaceae	*Lolium temulentum* L.	Naturalised	Eur	Graminoid	1982c	20–100	1982	A	Dis, Tra				
Poaceae	*Paspalum dilatatum* Poir.	Invasive	S Am	Graminoid	1970h	20–100	2014	W	Dis, Tra				
Poaceae	*Paspalum distichum* L.	Invasive	S Am	Graminoid		20–100	2014	W	Dis, Tra			Y	
Poaceae	*Paspalum vaginatum* Sw.	Invasive	S Am	Graminoid	1999h	20–100	2014	W	Dis, Tra				
Poaceae	*Paspalum urvillei* Steud.	Invasive	S Am	Graminoid		20–100	2014	W	Dis, Tra			Y	

Table 2 (*continued*)

Family	Species	Invasion status	Origin	Growth form	First record	Residence time	Most recent record	Reason for introduction	Habitat	CARA	NEMBA	SAPIA	Control
Poaceae	*Pennisetum clandestinum* Hochst. ex Chiov.	Invasive	Afr	Graminoid		20–100	2014	H	Dis, Tra		1b	Y	M,C
Poaceae	*Pennisetum setaceum* (Forssk.) Chiov.	Invasive	Afr, Eur	Graminoid		20–100	2014	H	Dis, Tra	1	1b	Y	C
Poaceae	*Phalaris arundinacea* L.	Naturalised	Eur	Graminoid	1998h	20–100	1998	A,H	Fyn, Dis				
Poaceae	*Poa annua* L.	Invasive	Eur	Graminoid	1993h	20–100	2014	M	Dis, Tra				
Poaceae	*Poa pratensis* L.	Invasive	Eur	Graminoid	1966h	20–100	1989	G,H	Dis				
Poaceae	*Polypogon monspeliensis* (L.) Desf.	Invasive	Eur	Graminoid	1966h	<20	2014	W	Fyn				
Poaceae	*Setaria geniculata* P. Beauv.	Invasive	Eur	Graminoid	1998h	20–100	2014	W	Tra				
Poaceae	*Setaria megaphylla* (Steud.) T. Durand & Schinz	Invasive	Afr (SA)	Graminoid		20–100	2014	H	For, Dis				
Poaceae	*Vulpia bromoides* (L.) Gray	Naturalised	Med	Graminoid	1982c	20–100	1982	W	Wet, Tra				
DICOTYLEDONS													
Acanthaceae	*Thunbergia alata* Bojer ex Sims	Naturalised	Afr (SA)	Creeper		20–100	2014	E,H	Dis, Tra				
Adoxaceae	*Sambucus nigra* L.	Invasive!	Eur	Shrub		20–100	2014	H	Dis, Tra		1b	Yx	M,C
Amaranthaceae	*Achyranthes aspera* L.	Invasive	Afr,Eur	Herb		20–100	2014	E,M	Dis, Tra			Y	
Anacardiaceae	*Schinus terebinthifolia* Raddi	Casual	S Am	Tree		20–100	2014	H	Tra	3	1b		
Apiaceae	*Apium graveolens* L.	Naturalised	Eur	Herb	1966h	20–100	1966	E	Fyn				
Apiaceae	*Cyclospermum leptophyllum* (Pers.) Sprague	Invasive	N Am, S Am	Herb		20–100	2014	E	Dis, Tra				
Apiaceae	*Foeniculum vulgare* Mill.	Naturalised	Med	Herb		20–100	2014	E,M	Dis, Tra			Y	
Apocynaceae	*Catharanthus roseus* (L.) G. Don	Naturalised	Afr	Herb		20–100	2014	M	Dis, Tra		1b		
Apocynaceae	*Nerium oleander* L.	Naturalised	Eur	Tree	1985c	20–100	2014	H	Tra	1	1b	Y	M,C
Apocynaceae	*Vinca major* L.	Naturalised	Eur	Creeper		20–100	2014	M	Dis, Tra		1b	Y	
Asteraceae	*Aster squamatus* (Spreng.) Hieron.	Naturalised	N Am, S Am	Herb	1982c	20–100	1982	W	Wet				
Asteraceae	*Bidens pilosa* L.	Invasive	S Am	Herb		20–100	2014	M,W	Dis, Tra				
Asteraceae	*Cirsium vulgare* (Savi) Ten.	Invasive	Eur, Med	Herb		20–100	2014	H	Dis, Tra	1	1b	Y	M
Asteraceae	*Dittrichia graveolens* (L.) Greuter	Naturalised	Med	Herb	1982c	20–100	1982	W	Dis				
Asteraceae	*Erigeron bonariensis* L.	Invasive	S Am	Herb		20–100	2014	W	Dis, Tra				
Asteraceae	*Erigeron canadensis* L.	Invasive	S Am	Herb		20–100	2014	M,W	Dis, Tra				
Asteraceae	*Facelis retusa* (Lam.) Sch.Bip.	Naturalised	S Am	Herb	1982c	20–100	1998	W	Wet, Dis				
Asteraceae	*Galinsoga parviflora* Cav.	Invasive	S Am	Herb	1998h	20–100	2014	W	Dis, Tra				
Asteraceae	*Gamochaeta coarctatum* Willd.	Invasive	S Am	Herb		<20	2014	W	Dis, Tra				
Asteraceae	*Helminthotheca echioides* (L.) Holub	Invasive	Eur	Herb		20–100	2014	E	Dis, Tra				
Asteraceae	*Hypochaeris glabra* L.	Invasive	Eur	Herb	2011h	<20	2014	W	Fyn, Dis				
Asteraceae	*Hypochaeris radicata* L.	Invasive	Eur	Herb	1966h	20–100	2014	M	Dis, Tra				
Asteraceae	*Lactuca serriola* L.	Invasive	Eur, Med	Herb		20–100	2014	E,M	Tra				
Asteraceae	*Sonchus asper subsp. asper* (L.) Hill	Invasive	Eur	Herb		20–100	2014	W	Dis, Tra				
Asteraceae	*Sonchus oleraceus* (L.) L.	Invasive	Eur	Herb		20–100	2014	M,W	Dis, Tra				
Asteraceae	*Tagetes minuta* L.	Invasive	S Am	Herb		20–100	2014	A,W	Dis, Tra				
Asteraceae	*Taraxacum officinale* (L.) Weber ex F.H. Wigg.	Invasive	Eur	Herb		20–100	2014	M,W	Dis, Tra				
Asteraceae	*Xanthium spinosum* L.	Naturalised	S Am	Shrub	2011h	<20	2014	A	Tra	1	1b		
Azollaceae	*Azolla filiculoides* Lam.	Invasive	S Am	Herb		20–100	2014	H	Aqu	1	1b	Y	B
Basellaceae	*Anredera cordifolia* (Ten.) Steenis	Invasive!	S Am	Creeper		20–100	2014	H,M	For, Dis, Tra	1	1b	Y	M,C
Bignoniaceae	*Jacaranda mimosifolia* D. Don	Casual	S Am	Tree		20–100	2014	H	Tra	3			M,C
Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth	Casual	S Am	Creeper		20–100	2014	H	Tra			Y	C
Bignoniaceae	*Tecomaria capensis* (Thunb.) Spach	Invasive!	Afr (SA)	Creeper		20–100	2014	H	For, Dis, Tra				
Boraginaceae	*Anchusa azurea* Mill.	Invasive	Eur, Med	Herb		20–100	2014	H	Fyn, Dis				
Boraginaceae	*Myosotis sylvatica* Hoffm.	Invasive	Eur, Med	Herb	2008h	<20	2014	H	Dis				
Brassicaceae	*Capsella bursa-pastoris* (L.) Medik.	Invasive	Eur	Herb		20–100	2014	M	Dis, Tra				
Brassicaceae	*Cardamine hirsuta* L.	Invasive	Eur	Herb	2011h	<20	2014	E	Dis, Tra				
Brassicaceae	*Lepidium didymum* (L.) Sm.	Invasive	Eur, N Am	Herb		20–100	2014	E	Tra				
Brassicaceae	*Nasturtium officinale* R.Br.	Naturalised	Eur	Herb		<20	2011	E	Aqu	2	2	Y	

(*continued on next page*)

Table 2 (*continued*)

Family	Species	Invasion status	Origin	Growth form	First record	Residence time	Most recent record	Reason for introduction	Habitat	CARA	NEMBA	SAPIA	Control
Brassicaceae	*Raphanus raphanistrum* L.	Invasive	Eur	Herb		20–100	2014	E	Tra				
Cactaceae	*Opuntia ficus-indica* (L.) Mill.	Naturalised	S Am	Succulent	1985c	20–100	2014	E	Fyn, Tra	1	1b	Y	M,C
Cactaceae	*Opuntia monacantha* Haw.	Naturalised	S Am	Succulent		20–100	2014	A,H	Dis	1	1b	Y	M,C
Cactaceae	*Pereskia aculeata* Mill.	Naturalised	S Am	Creeper		20–100	2014	H	Dis, Tra	1	1b	Y	M,C
Cannabaceae	*Cannabis sativa* L.	Casual	Eur	Herb	1999h	20–100	2014	M	Tra				
Cannaceae	*Canna indica* L.	Naturalised	S Am	Herb	1966h	20–100	2014	H	Tra	1	1b	Y	C
Cannaceae	*Canna X generalis* L.H. Bailey	Naturalised	S Am	Herb		20–100	2014	H	Tra			Y	C
Caprifoliaceae	*Lonicera japonica* Thunb.	Naturalised	Eur	Creeper		20–100	2014	H	Dis		3		
Caryophyllaceae	*Silene gallica* L.	Invasive	Eur	Herb		20–100	2014	W	Dis, Tra				
Caryophyllaceae	*Spergularia media* (L.) C. Presl	Invasive	Eur	Herb	2009h	<20	2014	W	Fyn				
Caryophyllaceae	*Stellaria media* (L.) Vill.	Invasive	Eur	Herb	1966h	20–100	2014	M	Dis, Tra				
Casuarinaceae	*Casuarina equisetifolia* L.	Casual	Aus	Tree		20–100	2014	F	Tra	2	2		
Chenopodiaceae	*Atriplex semibaccata* R. Br.	Naturalised	Aus	Shrub	1982c	20–100	2014	G	Dis, Tra				
Chenopodiaceae	*Chenopodium album* L.	Invasive	Eur	Herb		20–100	2014	E,M	Wet, Dis, Tra				
Chenopodiaceae	*Chenopodium ambrosioides* L.	Invasive	S Am	Herb		20–100	2014	M	Wet, Dis				
Chenopodiaceae	*Chenopodium carinatum* R. Br.	Invasive	Aus	Herb		20–100	2014	W	Tra				
Chenopodiaceae	*Chenopodium murale* L.	Invasive	Eur	Herb		20–100	2014	E	Wet				
Commelinaceae	*Commelina benghalensis* L.	Naturalised	Afr, Eur	Herb		20–100	2014	E,H,M	Dis, Tra			Y	
Commelinaceae	*Tradescantia fluminensis* Vell.	Naturalised	S Am	Herb		20–100	2014	H	Tra		1b	Y	
Convolvulaceae	*Dichondra micrantha* Urb.	Invasive	Aus	Herb		20–100	2014	H	Dis, Tra				
Convolvulaceae	*Ipomoea cairica* (L.) Sweet	Invasive	S Am	Creeper	1982c	20–100	2014	H,M	Dis				M,C
Convolvulaceae	*Ipomoea indica* (Burm.f.) Merr.	Invasive	S Am	Creeper		20–100	2014	H	Dis, Tra	1	1b	Y	C
Convolvulaceae	*Ipomoea purpurea* (L.) Roth	Naturalised	S Am	Creeper	1999h	20–100	2014	H	For, Dis	3	1b	Y	C
Crassulaceae	*Bryophyllum delagoense* (Eckl. & Zeyh.) Druce	Invasive	Afr	Succulent		20–100	2014	H	Dis, Tra	1	1b	Y	M,C
Crassulaceae	*Crassula multiclava* Lem.	Invasive	Afr (SA)	Succulent		20–100	2014	H	For, Dis, Tra				
Crassulaceae	*Kalanchoe baharensis* Drake	Naturalised	Afr	Succulent		<20	2014	H	Dis, Tra				
Euphorbiaceae	*Euphorbia hirta* L.	Invasive	S Am	Succulent		20–100	2014	M,W	Tra				
Euphorbiaceae	*Euphorbia peplus* L.	Naturalised	Med	Herb		20–100	2014	M	Tra				
Euphorbiaceae	*Ricinus communis* L.	Invasive	Afr	Shrub	1985c	>100	2014	M	Fyn, Dis, Tra	2	2	Y	M
Fabaceae	*Acacia baileyana* F. Muell.	Naturalised	Aus	Tree		20–100	2014	H	Dis, Tra	3	3	Y	M,C
Fabaceae	*Acacia cyclops* G. Don	Transformer	Aus	Tree	1985c	20–100	2014	F	Fyn, Dis, Tra	2	1b	Y	M,C,B
Fabaceae	*Acacia dealbata* Link	Casual	Aus	Tree	1890i	>100		F	Dis	1	2	Y	M,C
Fabaceae	*Acacia decurrens* Willd.	Transformer	Aus	Tree		20–100	2014	F	Dis	2	2		M,C
Fabaceae	*Acacia elata* Benth.	Invasive!	Aus	Tree	1985c	20–100	2014	H	Dis	3	1b	Y	M,C
Fabaceae	*Acacia longifolia* (Andrews) Willd.	Transformer	Aus	Tree	1985c	20–100	2014	F	Fyn, Dis	1	1b	Y	M,C,B
Fabaceae	*Acacia mearnsii* De Wild.	Transformer	Aus	Tree	1890i, 1985c	>100	2014	F	Fyn, Wet, Dis, Rip, Tra	2	2	Y	M,C,B
Fabaceae	*Acacia melanoxylon* R.Br.	Transformer	Aus	Tree	1856i	>100	2014	F	For, Fyn, Rip, Tra	2	2	Y	M,C,B
Fabaceae	*Acacia podalyriifolia* G. Don	Invasive!	Aus	Tree		20–100	2014	H	Tra	3	1b	Y	M,C
Fabaceae	*Acacia saligna* (Labill.) Wendl.	Transformer	Aus	Tree	1985c	20–100	2014	F	Fyn, Tra	2	1b	Y	M,C,B
Fabaceae	*Acacia stricta* (Andrews) Willd.	Invasive!	Aus	Tree	2002h	<20	2014	F	Tra		1a	Y	M,C
Fabaceae	*Lotus subbiflorus* Lag.	Invasive	Med	Herb		20–100	2014	G	Tra				
Fabaceae	*Medicago polymorpha* L.	Invasive	Med	Herb		20–100	2014	G	Tra				
Fabaceae	*Medicago sativa* L.	Invasive	Eur	Herb	2012h	20–100	2014	G	Tra				
Fabaceae	*Melilotus indicus* (L.) All.	Invasive	Eur, Med	Herb		20–100	2014	G	Tra				
Fabaceae	*Melilotus officinalis subsp. alba* (Medik.) H. Ohashi & Tateishi.	Invasive	Eur, Med	Herb	1998h	20–100	2014	G	Tra				
Fabaceae	*Ornithopus sativus* Brot.	Invasive	Eur	Herb		20–100	2002	G	Dis, Tra				
Fabaceae	*Paraserianthes lophantha* (Willd.) I.C. Nielsen	Invasive!	Aus	Tree	1985c	20–100	2014	H	Fyn, Dis, Tra	1	1b	Y	M,C
Fabaceae	*Robinia pseudoacacia* L.	Invasive	N Am	Tree		20–100	2014	H	Tra	2	1b	Y	M,C
Fabaceae	*Senna didymobotrya* (Fresen.) H.S. Irwin & Barneby	Naturalised	Afr	Shrub		20–100	2014	H	Dis, Tra	3	1b	Y	M,C

Table 2 (*continued*)

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Fabaceae	*Senna septemtrionalis* (Viv.) H.S. Irwin & Barneby	Invasive	S Am	Shrub	1999h	20–100	2014	H	For, Dis, Tra		1b	Y	M,C
Fabaceae	*Sesbania punicea* (Cav.) Benth.	Invasive	S Am	Tree		20–100	2014	H	Dis, Tra	1	1b	Y	M,C,B
Fabaceae	*Tipuana tipu* (Benth.) Kuntze	Casual	S Am	Tree		20–100	2014	H	Tra	3	3		
Fabaceae	*Trifolium campestre* Schreb.	Invasive	Eur	Herb		<20	2014	G	Tra				
Fabaceae	*Trifolium pratense* L.	Invasive	Eur, Med	Herb		<20	2014	G	Tra				
Fabaceae	*Trifolium repens* L.	Invasive	Eur, N Am	Herb		20–100	2014	G	Tra				
Fabaceae	*Vicia hirsuta* (L.) Gray	Invasive	Eur	Creeper	1982c	20–100	1982	G	Dis, Tra				
Fabaceae	*Vicia sativa* L.	Invasive	Eur	Creeper		20–100	2014	G	Dis, Tra				
Fagaceae	*Quercus palustris* Muenchh.	Casual	N Am	Tree		20–100	2014	H	Tra			Y	
Fagaceae	*Quercus robur* (Ten.) A.DC.	Casual	Eur, Med	Tree	1856i, 1985c	>100	2014	H	For, Fyn, Tra			Y	M
Fumariaceae	*Fumaria muralis* Sond. ex W.D.J. Koch	Invasive	Afr, Eur	Herb		20–100	2014	M	Dis, Tra				
Geraniaceae	*Erodium moschatum* (L.) L'Hér.	Invasive	Eur, Med	Herb		20–100	2014	M,W	Dis, Tra				
Haloragaceae	*Myriophyllum spicatum* L.	Naturalised	Eur, Med	Herb	1982c	20–100		H	Aqu	1	1b		
Hydrangeaceae	*Hydrangea macrocarpa* Hand.-Mazz.	Naturalised	Eur	Shrub		<20	2014	H	Dis				
Lamiaceae	*Plectranthus barbatus* Andrews	Invasive	Eur	Herb		20–100	2014	H,M	Dis, Tra	3	1b	Y	M,C
Lauraceae	*Cinnamomum camphora* (L.) J. Presl	Invasive!	Eur	Tree		20–100	2014	F,H,M	Dis		1b	Y	M,C
Lythraceae	*Lythrum hyssopifolia* L.	Naturalised	Eur	Herb		<20	2014	W	Dis, Tra		1b		
Malvaceae	*Malva parviflora* L.	Naturalised	Med	Herb		<20	2014	W	Dis, Tra				
Meliaceae	*Melia azedarach* L.	Invasive!	Eur	Tree		20–100	2014	H	Tra	3	1b	Y	M,C
Moraceae	*Morus alba* L.	Casual	Eur	Tree		20–100	2014	E,H	Tra	3	3		
Myoporaceae	*Myoporum montanum* R.Br.	Invasive	Aus	Tree		20–100	2014	G	Dis, Tra	3		Y	
Myrtaceae	*Callistemon rigidus* R.Br.	Invasive!	Aus	Shrub		20–100	2014	H	Fyn, Dis, Tra		1b	Y	
Myrtaceae	*Corymbia ficifolia* (F. Muell.) K.D. Hill & L.A.S. Johnson	Casual	Aus	Tree		20–100	2014	H	Tra			Y	
Myrtaceae	*Eucalyptus camaldulensis* Dehnh.	Invasive	Aus	Tree	1890i	>100		F	Dis	2	1b	Y	M,C
Myrtaceae	*Eucalyptus diversicolor* F. Muell.	Invasive	Aus	Tree	1930i	20–100	2014	F	Fyn, Dis	2	1b	Y	M,C
Myrtaceae	*Eucalyptus globulus subsp. maidenii* (F. Muell.) J.B. Kirkp.	Naturalised	Aus	Tree	1856i	>100	2014	F	Fyn, Dis			Y	M,C
Myrtaceae	*Eucalyptus microcorys* F. Muell.	Casual	Aus	Tree	1930i	20–100	2014	F	Fyn			Y	M,C
Myrtaceae	*Eucalyptus muelleriana* Howitt	Casual	Aus	Tree	1930i	20–100	2014	F	Fyn				M,C
Myrtaceae	*Leptospermum laevigatum* (Gaertn.) F.Muell.	Invasive	Aus	Tree	1985c	20–100	2014	F,H	Dis, Tra	1	1b	Y	M,C
Myrtaceae	*Metrosideros excelsa* Sol. ex Gaertn.	Naturalised	Aus	Tree		20–100	2014	H	Tra				
Myrtaceae	*Psidium cattleianum* Afzel. ex Sabine	Invasive!	S Am	Tree		20–100	2014	E	Wet, Dis, Tra	3	1b	Y	M,C
Myrtaceae	*Psidium guajava* L.	Invasive	S Am	Tree		20–100	2014	E	Fyn, Dis, Tra	2	2	Y	M,C
Myrtaceae	*Syncarpia glomulifera* (Sm.) Nied.	Naturalised	Aus	Tree		20–100	2014	F	For				M,C
Myrtaceae	*Syzygium paniculatum* Gaertn.	Invasive	Aus	Tree		20–100	2014	H	For, Dis			Y	M,C
Oleaceae	*Fraxinus angustifolia* Vahl	Invasive	Eur, Med	Tree		<20	2014	H	Tra		3	Y	
Oleaceae	*Ligustrum japonicum* Thunb.	Naturalised	Eur	Shrub		20–100	2014	H	Dis, Tra	3	1b	Yx	
Onagraceae	*Fuchsia regia* (Vand. ex Vell.) Munz	Naturalised	S Am	Creeper	1998h	20–100	2014	H	For, Fyn, Dis			Yx	
Onagraceae	*Ludwigia palustris* (L.) Elliott	Invasive!	N Am, S Am	Herb	2014	<20	2014	H	Aqu				
Onagraceae	*Oenothera rosea* L'Hér. ex Aiton	Invasive	S Am	Herb		20–100	2014	H	Tra				
Onagraceae	*Oenothera stricta* Ledeb. ex Link	Invasive	N Am, S Am	Herb		20–100	2014	H	Tra			Y	

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Table 2 (*continued*)

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Oxalidaceae	*Oxalis corniculata* L.	Invasive	Eur	Herb		20–100	2014	H	Tra				
Oxalidaceae	*Oxalis latifolia* Kunth	Invasive	S Am	Herb	1966h	<20	2014	H	Tra				
Papaveraceae	*Argemone ochroleuca* Sweet	Invasive	S Am	Shrub		<20	2014	M,W	Tra	1	1b	Y	
Passifloraceae	*Passiflora caerulea* L.	Invasive	S Am	Creeper	1999h	20–100	2014	H	Dis, Tra	1	1b	Y	
Passifloraceae	*Passiflora edulis* Sims	Invasive	S Am	Creeper	1998h	20–100	2014	E	For, Dis		2	Y	M,C
Passifloraceae	*Passiflora mollissima* (Kunth) L.H. Bailey	Invasive	S Am	Creeper		20–100	2014	H	For	1			M,C
Phytolaccaceae	*Phytolacca americana* L.	Invasive	N Am	Shrub		20–100	2014	H,M	For		1b	Y	
Phytolaccaceae	*Phytolacca octandra* L.	Invasive	S Am	Shrub	1966h	20–100	2014	H,M	Dis, Tra				
Pittosporaceae	*Pittosporum undulatum* Vent.	Invasive	Aus	Tree		<20	2014	H	For, Dis, Tra	1	1b	Y	M,C
Plantaginaceae	*Plantago lanceolata* L.	Invasive	Eur	Herb	1998h	20–100	2014	M	Dis, Tra				
Plantaginaceae	*Plantago major* L.	Invasive	Eur	Herb	1966h	20–100	2014	M	Dis, Tra				
Polygonaceae	*Persicaria attenuata* (R. Br.) Soják	Invasive	Eur	Herb		20–100	2014	E,M	Dis,Wet				
Polygonaceae	*Persicaria lapathifolia* (L.) Delarbre	Invasive	Eur	Herb	1982c	20–100	2005	W	Wet				
Polygonaceae	*Rumex acetosella subsp. angiocarpus* (Murb.) Murb.	Invasive	Eur	Herb	1997h	20–100	2014	E,M	Tra				
Polygonaceae	*Rumex crispus* L.	Invasive	Eur	Herb	1966h	20–100	2014	E,M	Wet, Dis, Tra				
Portulacaceae	*Portulaca oleracea* L.	Invasive	Eur	Succulent		20–100	2014	E	Dis, Tra				
Primulaceae	*Anagallis arvensis* L.	Invasive	Eur	Herb		20–100	2014	H	Dis, Tra				
Proteaceae	*Grevillea robusta* A. Cunn. ex R.Br.	Invasive!	Aus	Tree		20–100	2014	H	Dis, Tra	3	3	Y	M,C
Proteaceae	*Hakea drupacea* R.Br.	Naturalised	Aus	Shrub	1985c	<20	2014	F	Fyn, Dis	1	1b	Y	M
Proteaceae	*Hakea gibbosa* Cav.	Naturalised	Aus	Shrub	1985c	20–100		H	Dis	1	1b	Y	M
Proteaceae	*Hakea salicifolia* (Vent.) B.L. Burtt	Invasive!	Aus	Shrub		20–100	2014	H	Fyn, Dis, Tra		1b	Y	M
Proteaceae	*Hakea sericea* Schrad. & J.C. Wendl.	Transformer	Aus	Shrub	1985c	20–100	2014	F	Fyn, Dis, Tra	1	1b	Y	M,B
Proteaceae	*Protea susannae* Phillips	Naturalised	Afr (SA)	Shrub		20–100	2014	H	Fyn, Dis				
Rosaceae	*Agrimonia procera* Wallr.	Naturalised	Eur	Creeper		20–100	2014	H,M	Dis, Tra		1b		
Rosaceae	*Cotoneaster franchetii* Bois	Invasive!	Eur	Tree		20–100	2014	H	For, Dis, Tra	3	1b	Y	
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	Invasive	Eur	Tree		20–100	2014	E	For	3	3	Y	M,C
Rosaceae	*Fragaria vesca* L.	Naturalised	Eur, N Am	Herb		<20	2014	H	Dis				
Rosaceae	*Prunus persica* (L.) Batsch	Naturalised	Eur	Tree		20–100	2014	E	Dis, Tra			Y	
Rosaceae	*Rosa multiflora* Thunb.	Naturalised	Eur	Shrub		20–100	2014	H	Tra			Y	M,C
Rosaceae	*Rosa rubiginosa* L.	Naturalised	Eur, Med	Shrub		20–100	2014	H,M	Tra	1	1b	Y	M,C
Rosaceae	*Rubus affinis* Madden ex Hook.f.	Naturalised	Eur	Creeper		20–100	1982	E	Fyn, Dis				M,C
Rosaceae	*Rubus fruticosus* L.	Transformer	Eur, Med	Shrub		20–100	2014	E	For, Dis, Tra	2	2	Y	M,C
Rubiaceae	*Richardia brasiliensis* Gomes	Invasive	S Am	Herb		<20	2014	W	Tra				
Rutaceae	*Citrus limon* (L.) Osbeck	Casual	Eur	Tree		20–100	2014	E	For				
Salicaceae	*Populus x canescens* (Aiton) Sm.	Naturalised	Eur	Tree	1856i, 1985c	>100	2014	F,H	Dis	2	2	Y	M,C
Salicaceae	*Salix babylonica* L.	Casual	Eur	Tree		20–100	2014	H	Tra	2		Y	M,C
Scrophulariaceae	*Verbascum virgatum* Stokes	Invasive	Eur	Herb		<20	2014	H	Tra				
Scrophulariaceae	*Veronica persica* Poir.	Invasive	Eur	Herb		20–100	2014	H	Tra				
Solanaceae	*Cestrum laevigatum* Schltdl.	Invasive!	S Am	Tree		20–100	2014	H	Dis, Tra	1	1b	Y	M,C
Solanaceae	*Datura ferox* L.	Invasive	N Am, S Am	Herb		20–100	2014	M	Tra	1	1b		
Solanaceae	*Datura stramonium* L.	Invasive	N Am, S Am	Herb		20–100	2014	M	Tra	1	1b	Y	
Solanaceae	*Lycopersicon esculentum* Mill.	Invasive	S Am	Herb		<20	2014	E	Wet, Dis				
Solanaceae	*Nicandra physalodes* (L.) Gaertn.	Invasive	S Am	Herb		20–100	2014	E,M	Tra		1b		
Solanaceae	*Nicotiana glauca* Graham	Invasive	S Am	Tree	1985c	20–100	2014	H,M	Tra	1	1b	Y	M,C
Solanaceae	*Physalis peruviana* L.	Invasive	S Am	Herb		20–100	2014	E	Tra			Y	
Solanaceae	*Solanum betaceum* Cav.	Naturalised	S Am	Tree		20–100	2014	E	For, Tra		3	Y	M,C
Solanaceae	*Solanum chenopodioides* Lam.	Naturalised	S Am	Shrub	1966h	20–100	1966	M	Dis				
Solanaceae	*Solanum mauritianum* Scop.	Invasive!	S Am	Shrub	1985c	20–100	2014	H	For, Rip, Dis, Tra	1	1b	Y	M,C
Solanaceae	*Solanum nigrum* L.	Invasive	Eur	Herb		20–100	2014	M	For, Dis, Tra				
Solanaceae	*Solanum pseudocapsicum* L.	Invasive	S Am	Shrub		20–100	2014	H	For, Dis		1b	Y	

Table 2 (*continued*)

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Tropaeolaceae	*Tropaeolum majus* L.	Naturalised	S Am	Herb		20–100	2014	H	Dis, Tra			Y	
Urticaceae	*Urtica dioica* L.	Naturalised	Eur, Med, N Am	Herb		20–100	2014	E,M	Tra				
Verbenaceae	*Glandularia aristigera* (S. Moore) Tronc.	Invasive	S Am	Herb	2009h	<20	2014	H,M	Dis				
Verbenaceae	*Lantana camara* L.	Invasive	S Am	Creeper	1985c	20–100	2014	H	Dis	1	1b	Y	M,C
Verbenaceae	*Verbena bonariensis* L.	Invasive	S Am	Shrub	1975h	20–100	2014	W	Dis, Tra		1b	Y	
Verbenaceae	*Verbena litoralis* Kunth	Invasive	S Am	Shrub	2012h	<20	2014	W	Dis, Tra				
Zingiberaceae	*Alpinia zerumbet* (Pers.) B.L. Burtt & R.M.Sm.	Naturalised	Eur	Herb		20–100		H,M	Tra		3	Y	M,C
Zingiberaceae	*Hedychium coronarium* J. Koenig	Naturalised	Eur	Herb		20–100	2014	H,M	Tra	1	1b	Yx	M,C

numbers of alien species are the Fabaceae, Poaceae, Asteraceae, Myrtaceae and Solanaceae (Table 3). Not only does the Fabaceae account for the largest number of alien species, but also for a disproportionately large number of invasives and transformers. In terms of invasion status, 9% of the GRNP species are casual aliens, 27% are naturalised aliens, 59% are invasive, and 5% are transformers (Fig. 2a). Growth forms highly represented among alien species are herbs (35%), trees (25%), graminoids (13%), and shrubs (11%) (Fig. 3a). Continents from which the largest numbers of species originate are Eurasia, South (and Central) America, and Australasia, in decreasing order of importance (Fig. 3b). Few (18) species are from Africa, of which seven are from elsewhere in South Africa (i.e. extralimital). Only 5% of species are known to have been resident in the area for >100 years, whilst 82% have been resident for 20–100 years, and 13% have been recently introduced (Fig. 2a).

Habitat types within the park with the largest numbers of alien species are disturbed and transformed habitat (Fig. 3d). Among habitat types that are in a natural or near-natural state, fynbos has the largest number of alien species. Riparian habitat had few species of alien plants but all these are either invasive or transformers. Trees and shrubs comprised the majority of the alien species present in forest, fynbos and riparian habitat, whereas graminoids were abundant in riparian and aquatic habitats (Fig. 4a). Herbaceous plants were the dominant alien growth form in wetlands and aquatic habitat, and also abundant in transformed and disturbed habitats. The most common reasons for (intentional) introduction were for horticultural-, medicinal-, edible- and forestry purposes (Fig. 3c). When considering habitat types separately, forestry species formed a large component of the aliens present in fynbos, riparian habitat and forest (Fig. 4b). Horticultural, medicinal and edible plants were common in most habitat types, with disturbed and transformed habitats having the most diverse array of reasons for introduction.

Table 3
Number of alien plant species per family and per invasion status for those families with more than two alien species in the Garden Route National Park.

Family	Total	Transformer	Invasive	Naturalised	Casual
Fabaceae	28	6	17	3	2
Poaceae	28		21	7	
Asteraceae	18		14	4	
Myrtaceae	13		8	2	3
Solanaceae	12		10	2	
Rosaceae	9	1	2	6	
Pinaceae	6	2	2	2	
Proteaceae	6	1	2	3	
Brassicaceae	5		4	1	
Chenopodiaceae	5		4	1	
Convolvulaceae	4		4		
Onagraceae	4		3	1	
Polygonaceae	4		4		
Verbenaceae	4		4		
Apiaceae	3		1	2	
Apocynaceae	3			3	
Asparagaceae	3			2	1
Bignoniaceae	3		1		2
Cactaceae	3			3	
Caryophyllaceae	3		3		
Crassulaceae	3		3		
Cyperaceae	3		3		
Euphorbiaceae	3		2	1	
Passifloraceae	3		3		

Only 31% (75) of GRNP alien plant species are on the CARA (see Table 1) list, whilst 39% (95 species) are on the draft NEMBA (see Table 1) list — 29% being Category 1, 6% Category 2, and 4% Category 3 invaders in the Western or Eastern Cape Provinces. All GRNP transformers are NEMBA-listed, but 96 species which we considered to be invasive in the GRNP are not listed by NEMBA (Fig. 2b). A large number of species (141; 58%) on our list have not been recorded by SAPIA (see Table 1) for the region of the GRNP, whilst 37 species have been recorded by SAPIA in the region but not by us. Of these, 11 species were not observed by us, 18 species occurred within the region but outside of the park, and eight were associated with identification uncertainty at species-level. The most common types of error or uncertainty associated with alien checklists that affected our compilation were (i) species identification or taxonomic uncertainty, and (ii) uncertainty of presence, extent and population dynamics of species due to inadequate survey data (Table 4).

Control measures have been implemented for 85 (35%) alien species in the GRNP, including all transformers, 29% of invasives, 37% of naturalised, and 35% of casual aliens. Of the 95 NEMBA-listed species, 69 are being controlled, whilst 20 Category 1 species, two Category 2 species and four Category 3 species are currently not controlled.

4. Discussion

Among South African NPs, the GRNP is only second to Kruger NP in terms of alien plant species richness (Spear et al., 2011). The large area of Kruger NP, as well as the inclusion of garden plants from staff villages in the list (Foxcroft et al., 2003) contribute to the richness of its alien flora. We have excluded garden plants from the GRNP list unless they exhibited signs of naturalisation or invasion. Table Mountain NP (Spear et al., 2011) and GRNP have comparably large numbers of alien plant species. Both parks are situated in the floristically diverse Cape Floral Kingdom, and conform to the positive correlation commonly observed between alien- and indigenous plant species richness (Richardson et al., 2005). In terms of family representation, the Poaceae, Asteraceae and Solanaceae rank highly in the alien plant floras of the GRNP, Kruger (Foxcroft et al., 2003) and Camdeboo (Masubelele et al.,

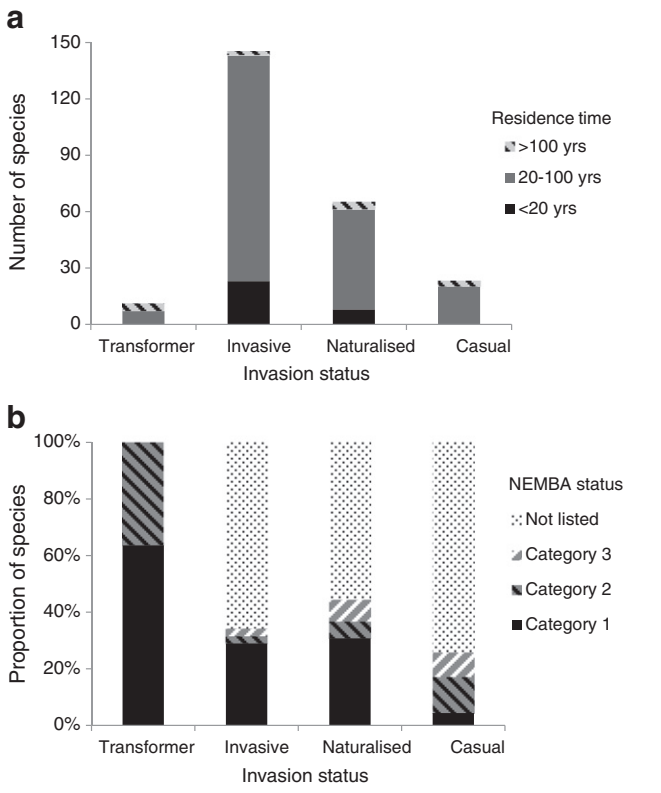

Fig. 2. (a) Number of alien plant species per invasion status and in terms of residence time, and (b) proportion of these alien species listed by NEMBA (National Environmental Management: Biodiversity Act 10 of 2004).

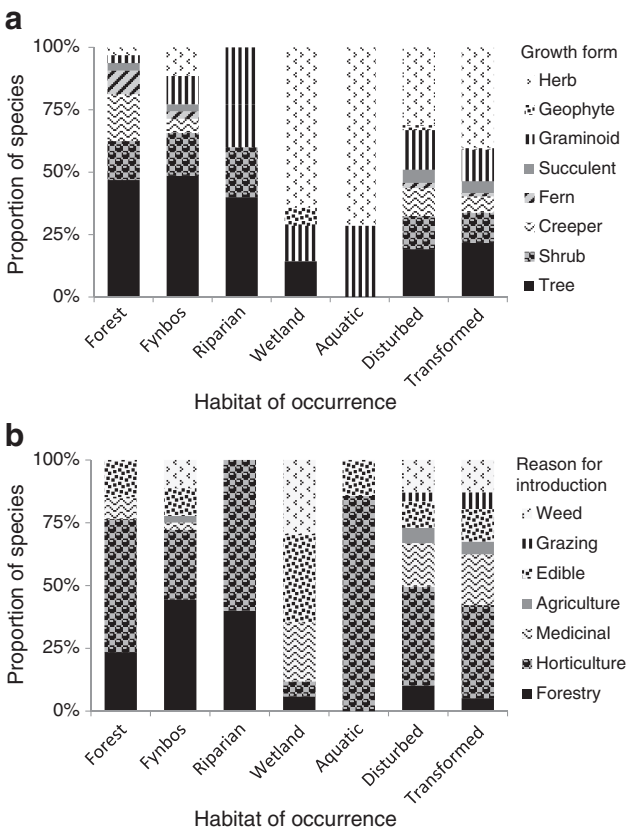

Fig. 4. Proportion of alien plant species in each habitat type per (a) growth form, and (b) reason for introduction.

2009) NPs, whilst the GRNP has a disproportionately large number of alien species of Fabaceae (as elsewhere in fynbos; Henderson, 2007), and fewer species of Cactaceae and Euphorbiaceae.

Not only does the GRNP have a large number of alien plants, the proportion of more aggressive alien species (i.e. invasives and transformers) is high (64% of total) compared to those recorded in

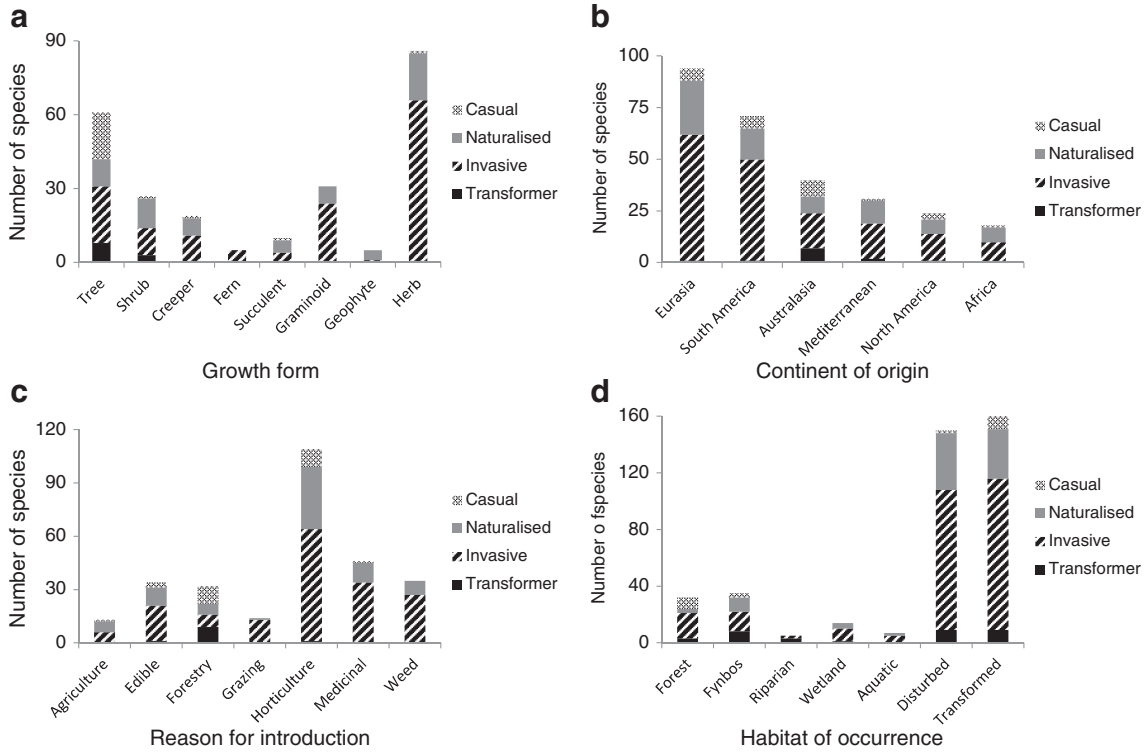

Fig. 3. Number of alien plant species per invasion status and in terms of (a) growth form, (b) continent of origin, (c) reason for introduction, and (d) habitat of occurrence.

Table 4
Incidence of different sources of error or uncertainty (after McGeoch et al., 2012) in the alien plant species list of the Garden Route National Park (GRNP).

Error type	Incidence	Comments
1. Human error	Unlikely	Synonyms were removed with nomenclature following 'The Plant List' (http://www.theplantlist.org/).
2. Incomplete information searches	Rare	Effect likely to be small, given size of study area and familiarity of authors with local literature.
3. Species identification/taxonomic uncertainty	Occasional	20 species recorded in literature or herbarium collections were not observed by us — species may have been identified incorrectly. 8 SAPIA (Southern African Plant Invaders Atlas) species not identified to species level — uncertain if same species as ours.
4. Survey data on presence, extent and population dynamics outside of indigenous range	Occasional	Inadequate data occasionally constrained designation of invasion status. Comprehensive presence/absence surveys virtually unachievable for an area the size of the GRNP.
5. Resolution of data and scaling of 'alien range'	Rare	Data collected at the same scale as study area. Limited uncertainty associated with SAPIA quarter degree square data extending beyond park boundary.
6. Data and knowledge not documented	Rare	Effect likely to be small given that data were collected over an extended period and various local specialists asked for input.
7. Documented data and knowledge not readily/widely accessible	Rare	Study conducted by local researchers with good access to relevant grey literature.
8. Baseline information on indigenous range (extralimital species)	Rare	Discrepancies between Germishuizen et al. (2006) and Manning and Goldblatt (2012) exist for two of our extralimital species (*Setaria megaphylla*, *Tecomaria capensis*) and one alien species (*Achyranthes aspera*). Two species (*Samolus porosus*, *Rumex saggitatus*) in the park are listed by SAPIA but considered indigenous by Germishuizen et al. (2006) and Manning and Goldblatt (2012).
9. Research on biodiversity impact inadequate	Unlikely	To compile our list of alien plants, we strictly followed the definitions of Richardson et al. (2000) and Pyšek et al. (2004) that are largely based on extent of spread, rather than biodiversity impact information.
10. Designation of invasion status; approach differs	Rare	We strictly applied the definitions of Richardson et al. (2000) and Pyšek et al. (2004) to species observed by us, but uncertainty existed in the case of species derived from the literature/herbaria and not observed by us.

other parks (Kruger NP 33%, Foxcroft et al., 2003; Camdeboo NP 46%, Masubelele et al., 2009). A long history of forestry and extensive planting has contributed significantly to the alien plant infestation in the Garden Route region, with transformers almost exclusively being trees or shrubs introduced from Australasia for forestry purposes or sand stabilisation (Wells et al., 1986; Henderson, 2007). Comparative analyses of alien flora (e.g. among protected areas) are restricted by the limited number of alien plant checklists published for the particular purpose and differences in the comprehensiveness of these lists (Spear et al., 2011). Discrepancies in the allocation of invasion status (or changes over time in the invasion status of species) may be real or attributable to assessors' differential interpretation of invasiveness, hence the need for standardisation of terminology and assessment approach (Richardson et al., 2000; Pyšek et al., 2004). We quantified or qualified the potential incidence of uncertainty in our list to facilitate more accurate comparisons and detection of future trends (McGeoch et al., 2012). The listing exercises for the three mentioned parks all followed Richardson et al. (2000), suggesting that the greater proportion of invasives in the GRNP is real. The inclusion of casual aliens from staff villages in the Kruger NP list (but not in the GRNP list) may also have reduced the proportion of invasives in Kruger NP. A large number (96) of GRNP invasive species were not listed by NEMBA as requiring regulation. Many (61%) of these are herbaceous plants. The discrepancy may in part reflect local differences in invasive status of species not captured at the national/provincial scale that NEMBA is aimed at, or differences in intent with the lists. However, we suggest that all invasives on our list be considered for inclusion in the NEMBA list.

The pressure of plant invasion in the GRNP appears to be escalating. We recorded 31 species with an estimated residence time of <20 years, i.e. likely recent introductions, and 82 alien plant species have been added to the GRNP list subsequent to the compilation by Spear et al. (2011) (listing 162 species). Whilst invasion is a real trend, increases in awareness and survey effort in recent years also contribute to the expansion of alien plant lists. Less than half of our species are reflected by SAPIA for the region, highlighting the value of a comprehensive compilation like this to improve the currency and completeness of national databases. Expansions in alien plant infestations may also occur as a result of control measures changing over time. Large areas of mountain fynbos in what is currently the GRNP, were already considered to be deteriorating in 1985, largely through *Hakea* and *Pinus* invasions (Macdonald et al., 1985). This was followed by a 20-year period of management neglect related to land tenure insecurity (Kraaij et al., 2011) prior to the proclamation of the GRNP.

Alien plant population growth often shows a lag in the early stages of establishment and exponential growth once propagule pressure is sufficiently high (Rouget and Richardson, 2003). Our observations spanning 30 years and relevant literature (e.g. Southwood, 1985) confirm that some species have become increasingly troublesome in the study area. We distinguished 21 species that appear to have become more evident in the region, posing emerging or escalating threats to indigenous biodiversity (indicated as 'Invasive!' in Table 2). These species should be the focus of intensified control and regulatory measures. Two GRNP species were identified by the South African National Biodiversity Institute's Invasive Species Programme as emerging plant invaders targeted for early detection and rapid response (Wilson et al., 2013).

An eradication attempt focussed in the study area is currently in progress for *Acacia stricta*, whilst risk assessment and eradication planning are done for *Iris pseudacorus*, although Wilson et al. (2013) seem to have been unaware of naturalised populations of this species in the Western Cape.

Transformed and disturbed habitats in the GRNP are the most invaded, but these are comparatively small in extent, generally invaded by non-woody taxa (Macdonald and Richardson, 1986), and already ecologically compromised. Trees, shrubs and creepers are the growth forms able to successfully invade forest, particularly forest margins and large forest gaps (Geldenhuys et al., 1986). The greatest threat of IAPs to biodiversity is to the fynbos and riparian habitat of the GRNP. Fynbos, being a fire-driven system, is particularly susceptible to invasion by alien trees and shrubs that are fire-adapted (Macdonald and Richardson, 1986; Richardson et al., 1992). *Pinus* and *Hakea* species are serotinous, with winged seeds released and spread *en masse* post fire. The Australian Acacias produce copious amounts of hard-coated, long-lived, soil-stored seeds that are stimulated by fires to germinate, in addition to adult plants being able to resprout after fire. Fynbos is virtually treeless, and invasion by trees and large shrubs (e.g. *Pinus*, *Eucalyptus*, *Acacia* and *Hakea*) are of particular concern due to increases in fuel load, shading-out of indigenous species, modification of soil properties and increased water consumption (Macdonald et al., 1985; Macdonald and Richardson, 1986; Van Wilgen et al., 2008). Riparian habitats are severely affected by *Acacia* invasion (particularly *A. mearnsii* and *A. melanoxylon*), with seeds dispersed downstream by water, and flooding and associated sediment dynamics facilitating further invasion (Richardson and Kluge, 2008). Management of IAPs in fynbos and riparian habitat is thus a priority in the GRNP and should take cognisance of disturbance events in space and time.

With increasing pressure from a large suite of alien plant species, and ongoing natural and anthropogenic disturbances operating in and around the park, the GRNP faces considerable challenges in protecting its rich native biodiversity. Substantial and sustained management actions will be required to reduce and mitigate impacts from biological invasions in these areas (Richardson et al., 2005). Maintaining updated checklists can assist with monitoring of changes in the numbers and invasion status of IAPs in protected areas as measures of the threat that IAPs pose to biodiversity. We have also demonstrated the use of such lists to evaluate current, and prioritise future, management actions aimed at the control of IAPs.

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